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APPLICATION NUMBER: *60/417,273*
FILING DATE: *October 08, 2002*
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

Express Mail Label No. EV151113582US

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Dror	Shemesh	Petah, Tikva, Israel

☐ *Additional Inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

Detection of Voids in Conductive Materials

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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OR

08791

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 19
☐ Drawing(s) *Number of Sheets*
☐ Application Data Sheet. See 37 CFR 1.76
☐ CD(s), Number
☐ Other (specify)

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.
☒ A check or money order is enclosed to cover the filing fees
☒ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 02-2666
☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): $160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No
☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE _____ Date 10/8/2002

TYPED or PRINTED NAME Tarek N. Fahmi REGISTRATION NO. *(if appropriate)* 41,402

TELEPHONE (408) 947-8200 Docket Number: 6317P004Z

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1 51 The information is used by the public to file (and by the PTO to process) a provisional application Confidentiality is governed by 35 U S C 122 and 37 CFR 1 14 This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form and/or suggestions for reducing this burden should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, DC 20231.

[redacted]

UNITED STATES PROVISIONAL PATENT APPLICATION

For

DETECTION OF VOIDS IN CONDUCTIVE MATERIALS

Inventor

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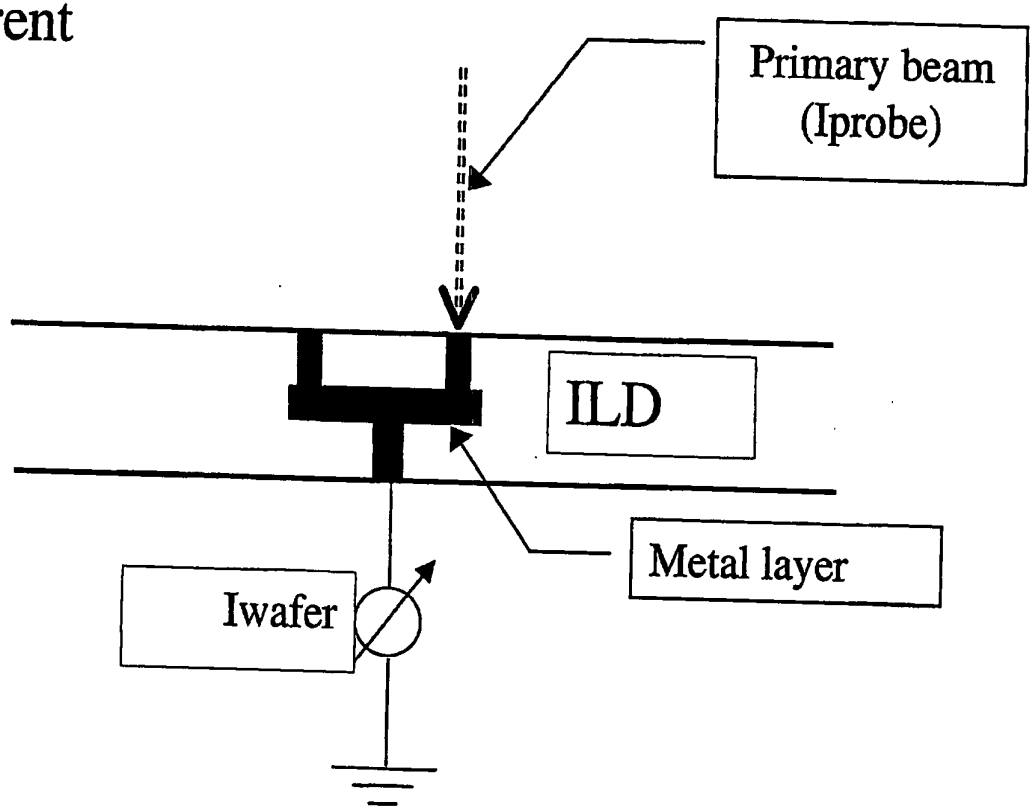
DETECTION OF VOIDS IN CONDUCTIVE MATERIALS

[0001] Detection of voids (especially sub-surface)within conductive materials such as copper may be based upon X-ray emission resulting from directing an electron beam to the conductive material. The X-ray emission may be generated during an EDX process.In cases where a conductor is surrounded or at least partially surrounded by non-conductive material (such as silicon oxide), voids cause a change in the spectrum of the emitted x-rays. The change results from the difference in the x-ray emission path resulting from the void. The energy of the electron beam shall enable the penetration of electrons and the emission of x-rays from throughout the conductive material. In such a case the EDX methods may be implemented for measuring the thickness of the conductive and non-conductive material. Such a measurement may be made after CMP polishing, for detecting "dishing", but may be otherwise implemented in areas where there is low probability to have voids. Such a location may be the center of a relatively large conductor (such as a conductive pad) or other parts that are distinct from the walls of the conductive materials.

[0004] Improved void detection may be achieved when more than a single detection/propagation paths are utilized. For example, by utilizing detectors for detecting x-rays from distinct angles, or when tilting the inspected object between measurements.

Possible SEM based methods to locate Cu voids

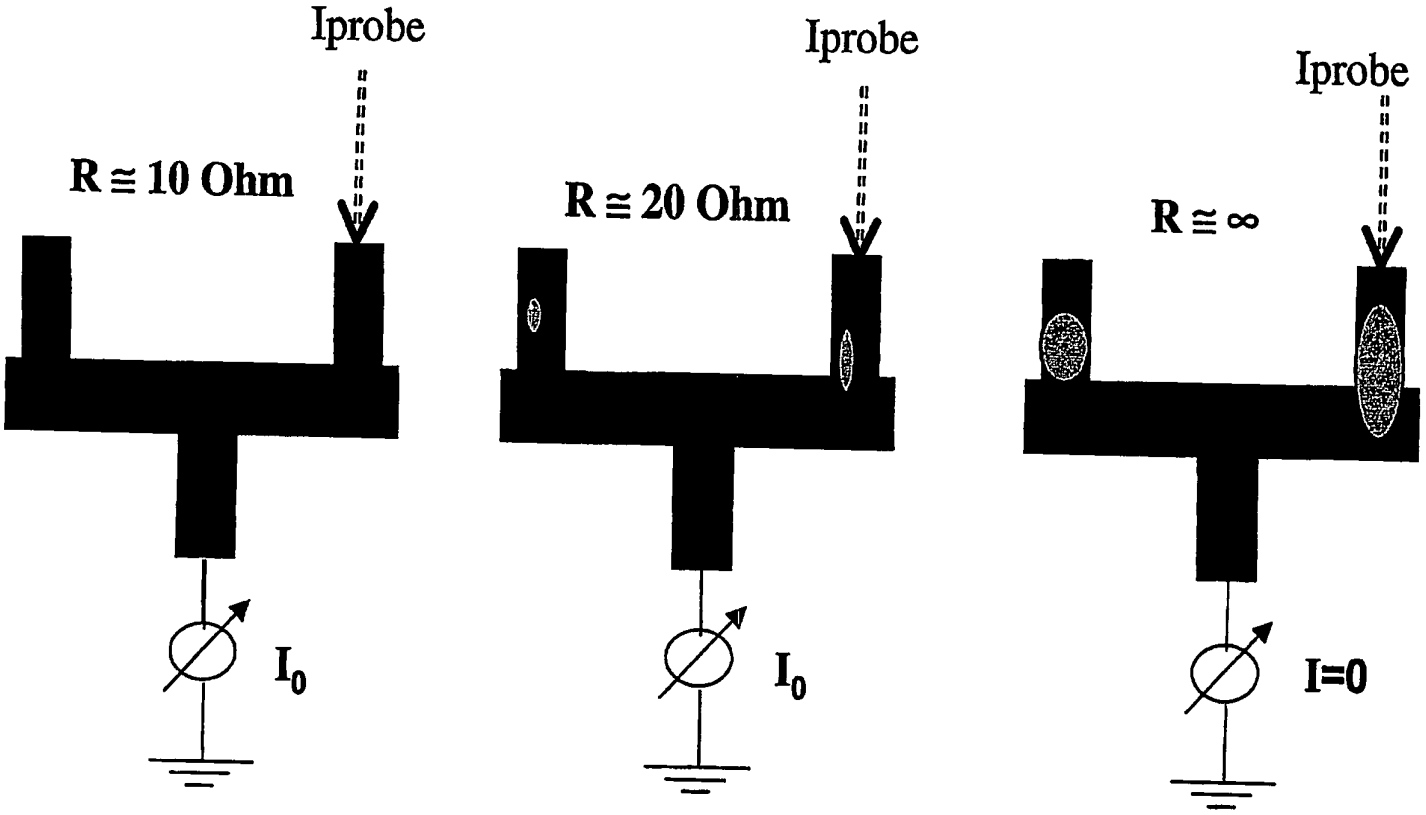
Wafer Current



The current through the Cu vias to the ground is measured

Possible SEM based methods to locate Cu voids

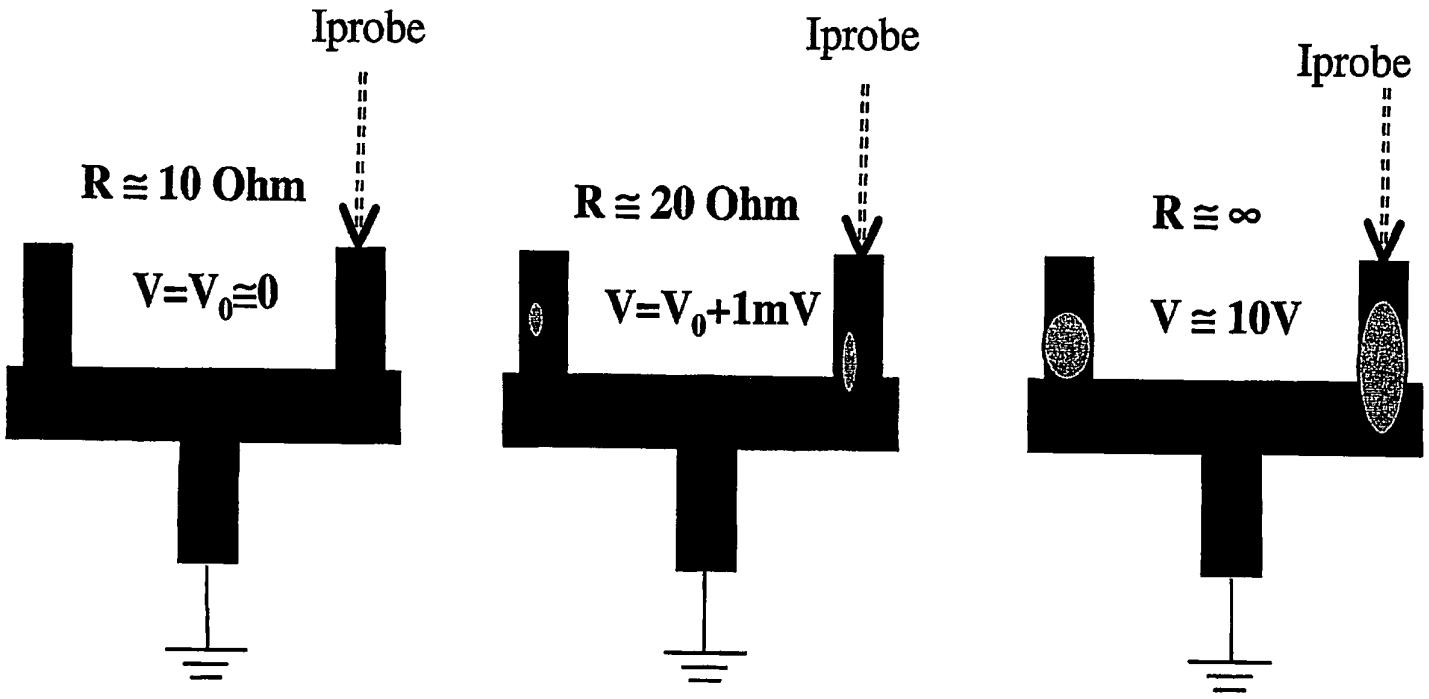
Wafer Current



As the electron gun is a current source, the current through the via will be constant as long as the via is conductive. Therefore, partial voids perturbations are undetectable

Possible SEM based methods to locate Cu voids

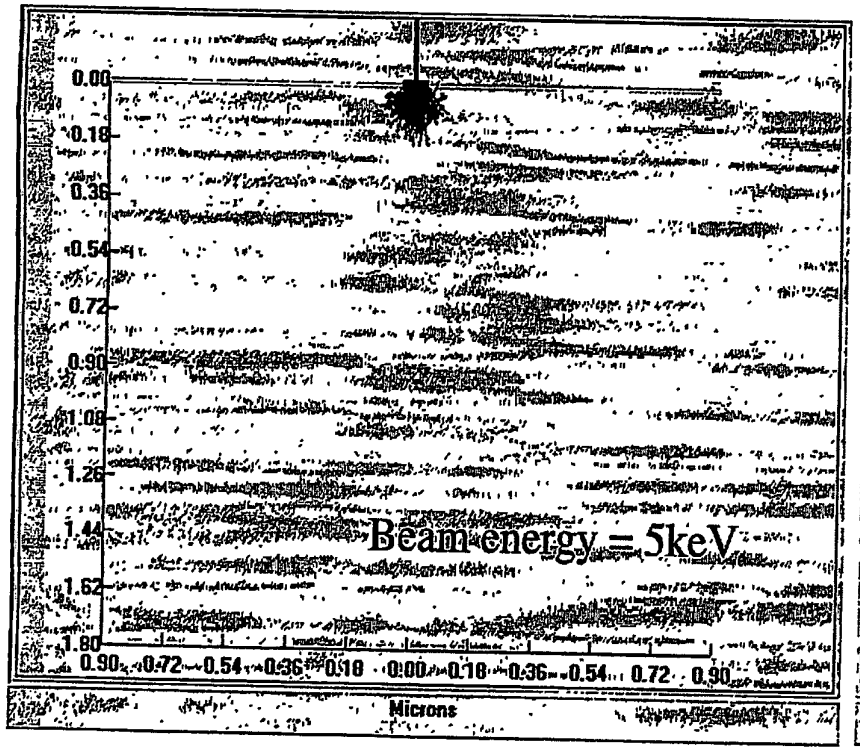
Voltage contrast



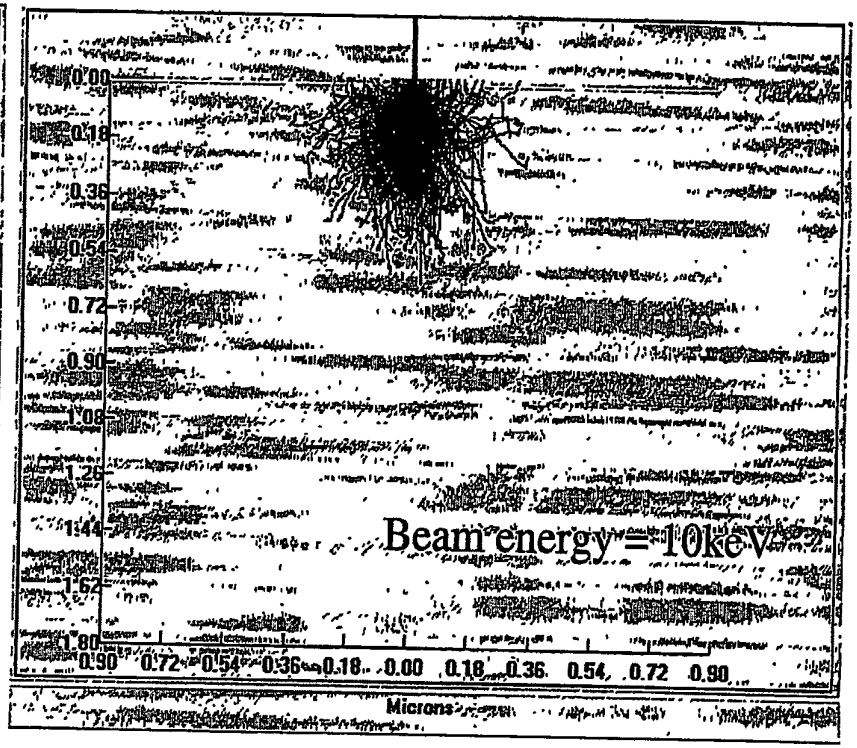
Voltage contrast appears only when the Cu Via is completely isolated. Therefore, Cu voids that do not cause a complete disconnection, cannot be detected.

Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis - interaction volume



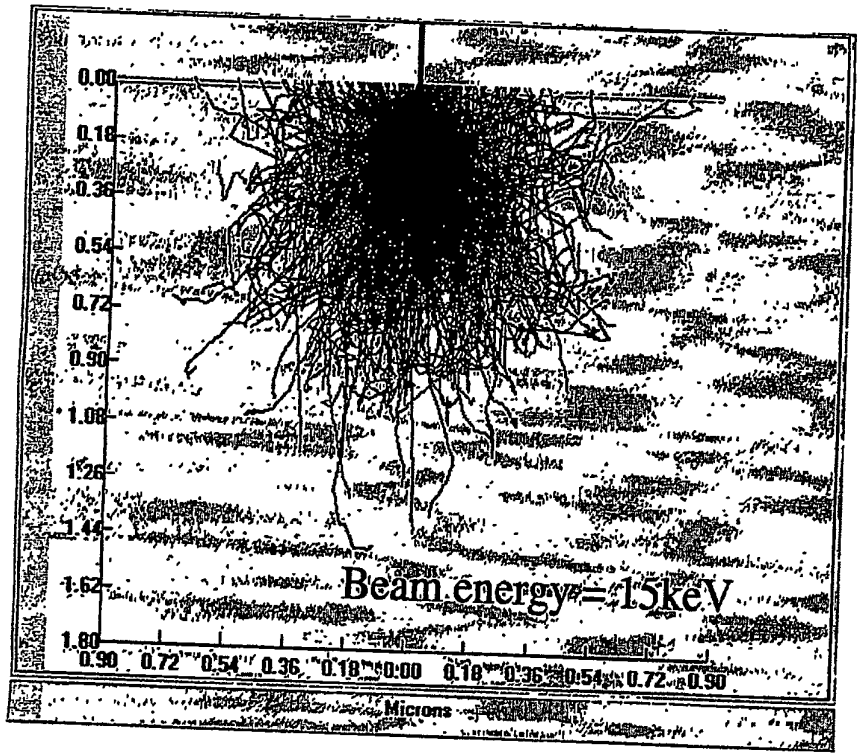
The penetration depth of the primary beam is 0.15 microns



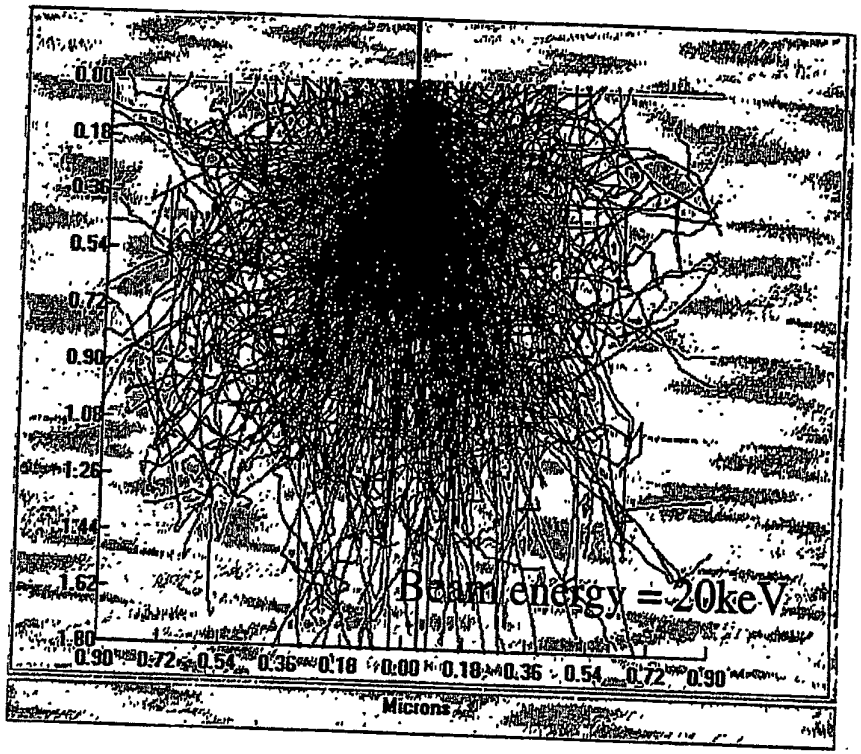
The penetration depth of the primary beam is 0.5 microns

Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis - interaction volume



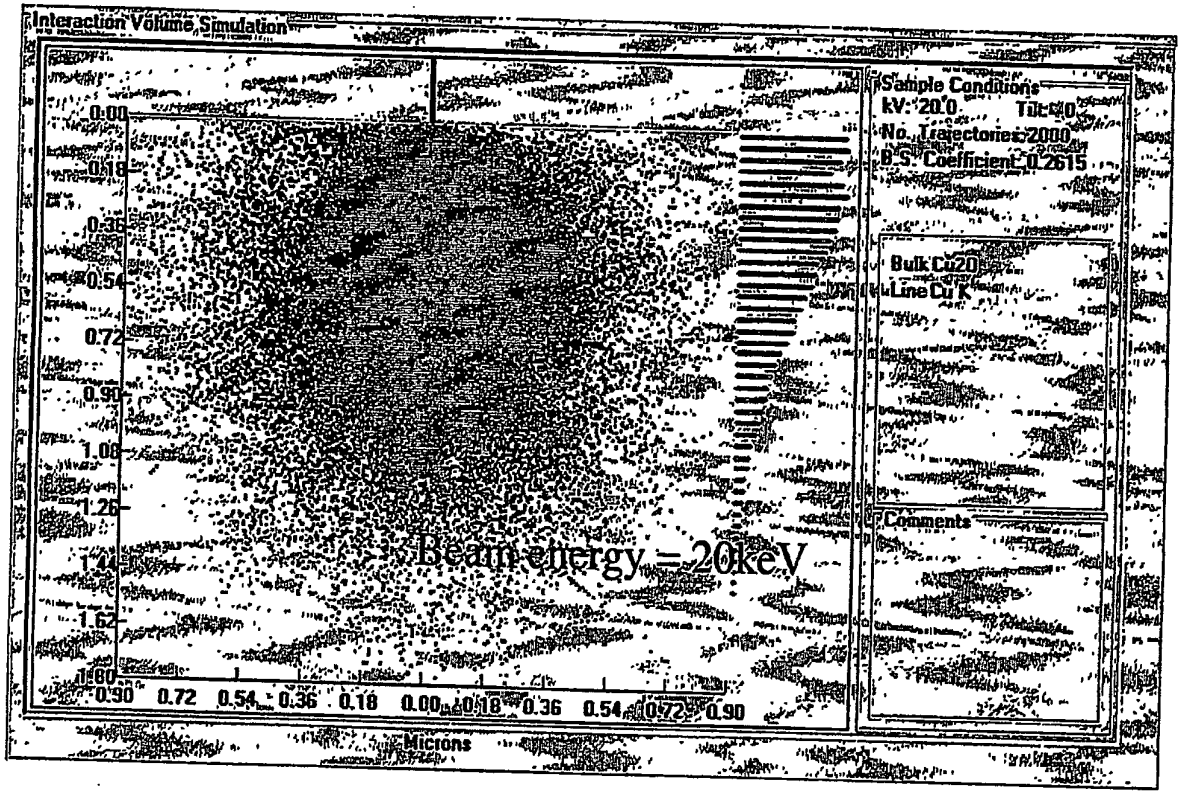
The penetration depth of the primary beam is 1 micron



The penetration depth of the primary beam is 1.6 microns

Possible SEM based methods to locate Cu voids

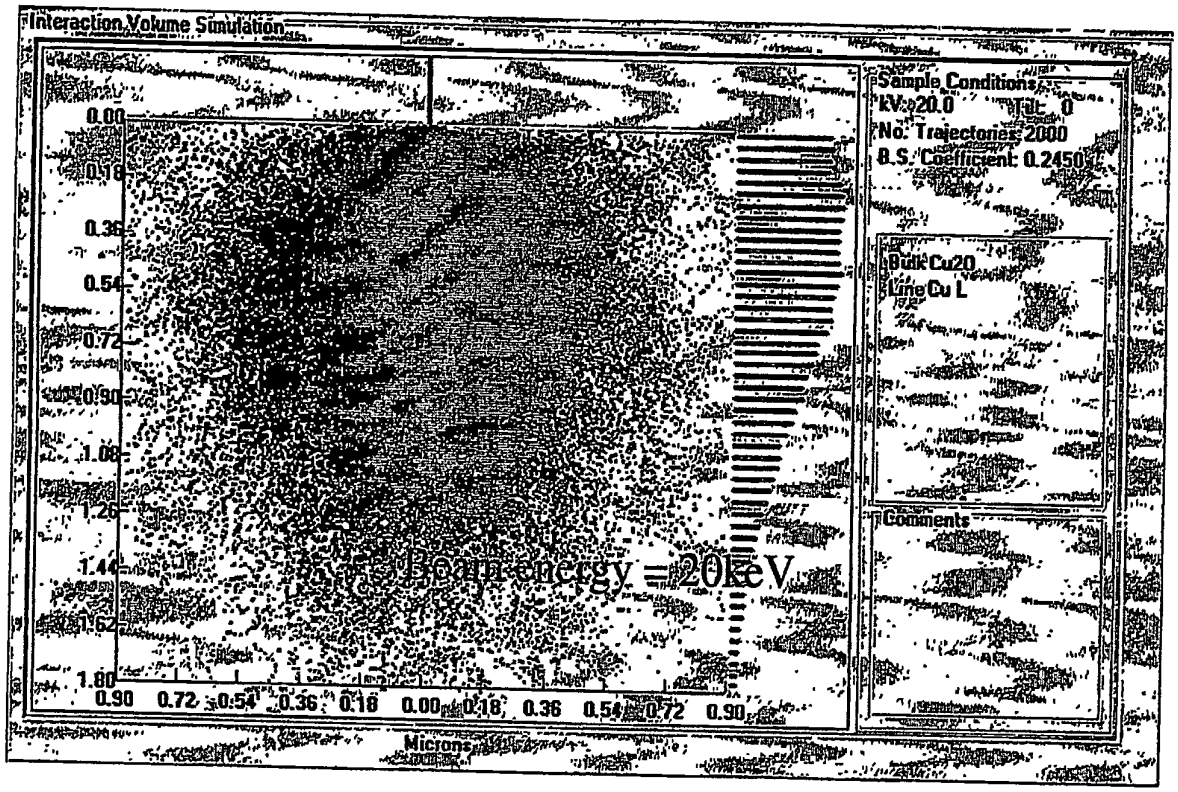
EDX Spectrum Analysis – X ray information volume



Cu K photons escape from 1.4 microns within the Cu bulk

Possible SEM based methods to locate Cu voids

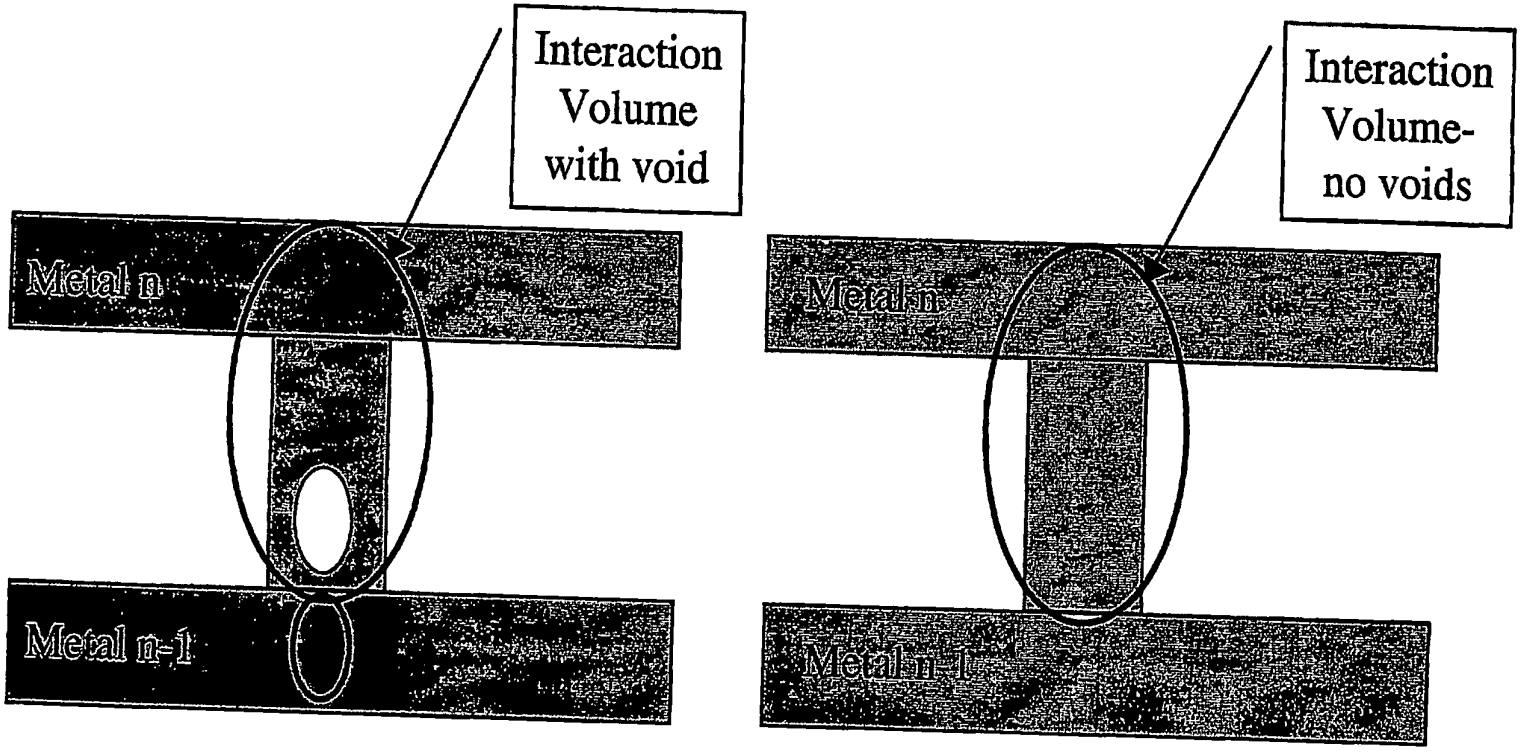
EDX Spectrum Analysis – X ray information volume



Cu L photons escape from 1.7 microns within the Cu bulk

Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – geometrical considerations



Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – geometrical considerations

- When voids exist in the Cu via, less x rays are emitted from the via, and more from Metal n-1 layer.
- As X ray signal decreases with the thickness, it will be weaker when voids exist.

Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – absorption considerations

$$I = I_0 \cdot e^{-\mu \cdot \rho \cdot t}$$

Where

μ is mass absorption coefficient

ρ is the density

t is the thickness

Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – absorption considerations

- The absorption coefficient μ of Cu L line is 1720 cm2/g For Cu, and 3893 cm2/g for SiO2
- The density ρ is equal to 8.95g/cm^3 for Cu, and 2.63g/cm^3 for SiO_2.

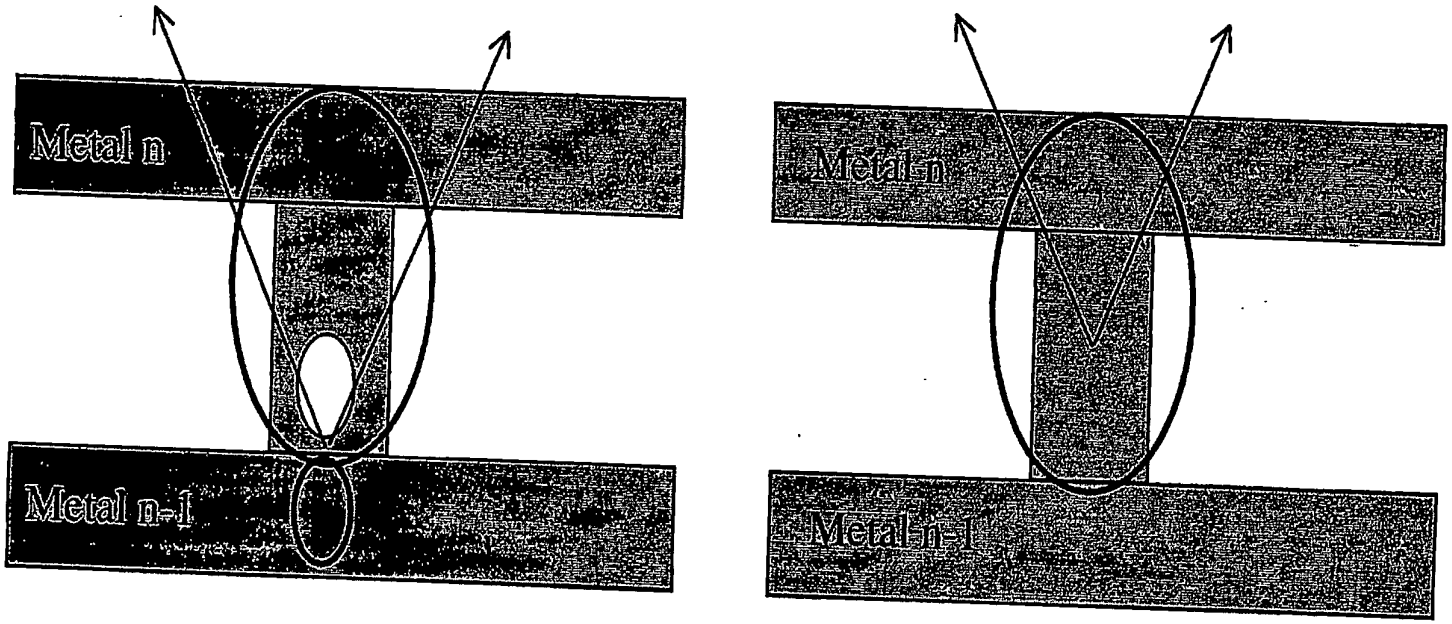
For t = 1 micron,

$$\frac{I}{I_0}(Cu) = 0.21 \qquad \frac{I}{I_0}(SiO_2) = 0.35$$

The absorption of Cu L line in Cu is 1.7 times higher than in SiO_2

Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – absorption considerations



When voids exist, the x-ray photon travels more in the Oxide and less in the Cu, therefore its absorption is smaller

Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – summary

- To penetrate into 1.5 micron deep, the beam energy of the SEM should be 20keV.
- The Cu L line carries information from deeper in the Cu via compares to Cu K lines. Therefore, to analyze voids that are deep in the Cu via, L line analysis is preferred.
- From geometrical considerations, the Cu Lα x-ray signal should be lower when voids exists.
- From absorption considerations, the Cu Lα x-ray signal should be higher when voids exists.

Experimental results and discussion

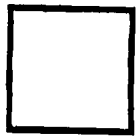
Column conditions

- The beam energy was set to 20keV. Although the standard Vacc range in the SEMVision G2 is 0.15 to 15kV, it could be set to 20kV without hardware modifications.
- The beam current was set to 400pA. We used the G2 multi hole aperture to achieve this beam current. No HW modifications are required.

Experimental results and discussion

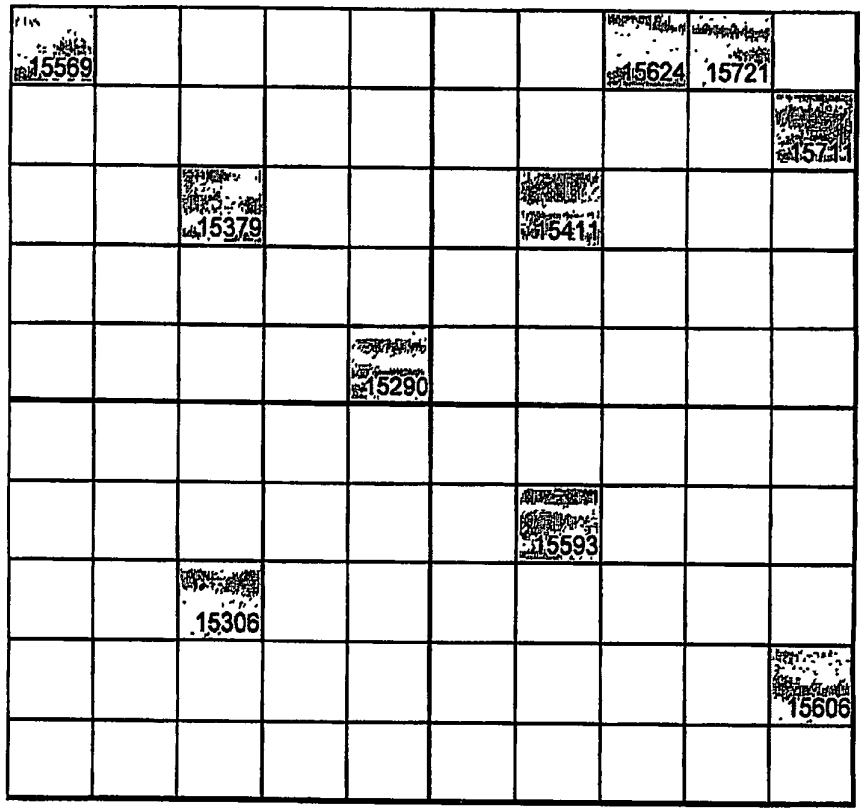
Wafer 3 results

- We scanned 20 seconds in FOV 14.6 microns, on the reported location
- We repeated the measurements on many dies across the wafer, and recorded the number of Cu Lα counts from each location



Experimental results and discussion

Wafer 3 results



Distribution of Cu Lα counts across the M3 wafer

Experimental results and discussion

Wafer 3 results – thickness variations measurements

- To correct for thickness variations, same dies were scanned, on locations were we assumed voids do not exist (for example on large pads).
- On M3 wafer, correlation was found between the thickness variations and the appearance of voids

A side effect of this work - thickness variations of Cu layers can be monitored using x-ray signal analysis

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